# A Review of Medical Image Watermarking Schemes

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**ABSTRACT :**Medical images plays an important role for clinical purposes and medical science. Medical image can be modified easily with existing image processing tools available today. The usage of security measures such as watermarking can protect the integrity of the images. This paper will review and compare few watermarking schemes for the usage in medical imaging. The quality issues to be considered before a watermarking scheme is chosen for implementation into existing medical information system will be discussed.

## INTRODUCTION

In a modern health care, system such as HIS (Hospital Information System) and PACS (Picture Archiving and Communications System) forms the information technology infrastructure for a hospital. Advancement of medical information system had changed the way patient records are stored, accessed and distributed. The integrity of the records such as medical images needs to be protected from unauthorized modification or destruction of information on the medical images. Current security measures used to protect the integrity of the patient records are such as VPN (Virtual Private Network), data encryption and data embedding [1]. Data encryption is being used on the Internet to protect sensitive data during its transmission. It is also being used to protect medical images in the form of digital signature. The problem with digital signature is that it needs to be transmitted together with the image in a separate file or in the image header. There is a risk of losing the signature in transmission. The signature will also be lost if there is no space in the header as the image file is converted to another format. Data embedding is where related information such as digital signature can be inserted into the medical images as a watermark. There is no standard of implementation and it is more difficult to be performed. But this technique offers advantages over VPN and data encryption. Watermark provides three objectives in medical images [2]:

• data hiding, for embedding information to make the image useful or easier to use;

• integrity control, to verify that the image has not been modified without authorization;

• authenticity, that is to verify that the image is really what the user supposes it is.

In this paper, we aim to provide a review of watermarking schemes used in medical imaging. In the first section, watermarking in medical images will be discussed. In the next section, current watermarking techniques and schemes for the usage in medical imaging will be reviewed and compared. The final section will discuss the quality issues to be considered before choosing a watermarking scheme.

## WATERMARKING IN MEDICAL IMAGES

Before proceeding to the watermarking schemes and methods, the foundation of watermarking, requirements in medical images, types of domain and performance measurement methods will be discussed in this section. As a basic, watermarking system is shown as below Fig 1.

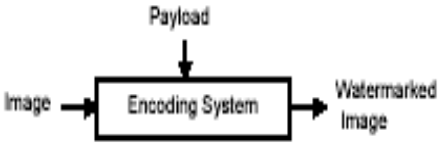


Figure 1. Embedding a payload


Figure 2. Recovering a payload

Fig. 1 Image watermarking

The encoder, E embeds the watermark, W inside original image I by using embedding function, E as shown in equation (1).

$$E(I, W) = IW \qquad (1)$$

The output from this process is IW, the watermarked image. The decoder, D will detect or extract the watermark, W from the original image as in equation (2).

$$D(I, IW) = W \qquad (2)$$



### Requirements

There are three requirements for medical image watermarking as mentioned by [2].

### Imperceptible/reversible

Medical images often not allowed to be modified in any way. Watermark scheme being used needs to be reversible and the exact pixel value needs to be recovered. The capacity and the number of possible methods had been limited significantly because of this requirement. An alternative in embedding the watermark is to define a ROI(Region of Interest). Once ROI is defined, watermark is embedded in the RONI(Region of Non Interest) to avoid modification in the ROI. Another method would be using the whole image for watermarking where imperceptible modification of the pixels is done.

### Integrity control

There is a need to decide when integrity control will take place. Medical images will often go through enhancements before it can be used. It is also necessary to decide the version of the image to be taken as the reference for integrity control.

**Authentication**

It is a critical requirement that the different part of the patient records can be authenticated such as the images. Usually, an attachment file or a header is used which consist of information to identify an image. This method does have it setback where separate file header is exposed to forgery and clumsy practices. An alternative is to embed the information into the image itself.

**Types of domain**

Watermarking techniques can be classified according to where the watermark is embedded namely spatial domain and transform domain.

**Spatial domain**

One of the most straight forward and simple technique is to embed the watermarking into the least significant bits of the image. Since the last binary bits are the least significant bits, its modification will not perceived by human eyes. This technique is not as robust as transform domain techniques and rarely survives various attacks.

**Transform domain**

Most of the transform domain techniques embed the information into the transform coefficients of the cover image. DCT (Discrete Cosine Transform), DWT (Discrete Wavelet Transform) and DFT (Discrete Fourier Transform) are the three popular methods in this category. Methods used needs a certain amount of computation but it can overcome possible compression and more robust against geometric transformation such as rotation, scaling, translation and cropping. In detail, DWT separates an image into lower resolution approximation image (LL) as well as horizontal (HL), vertical (LH) and diagonal (HH) detail components. The whole process then can be repeated to compute

multiple scale wavelet decomposition, as in the two scale wavelet transform shown in figure 2.

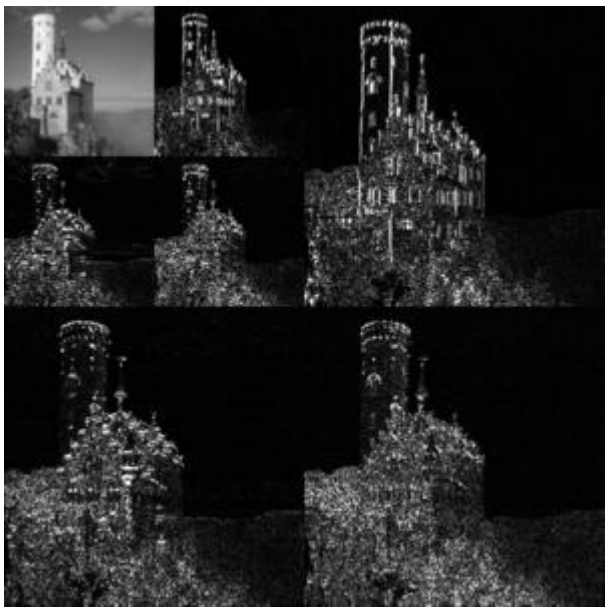

Figure 2 Wavelet transform

**Performance measures**

The performance of the watermarking is crucial to ensure the fidelity and quality of the watermarked images. Watermarking performance can be measured in terms of perceptibility. Below are two methods that can be used.

**MSE(Mean Square Error)**

MSE is one of the simplest functions to measure the perceptual distance between watermarked andunwatermarked images. This is defined as:

which is average term by term difference between the original image, I, and the watermarked image, I'.

**PSNR(Peak Signal to Noise Ratio)**

It is used to measure the similarity between images before or after watermarking. This is defined as:

where max I is the peak value of the original image.

**WATERMARKING SCHEMES**



In this section, few watermarking schemes will be reviewed and compared. In [3], dual watermarking was proposed by combining robust and fragile watermarking techniques. Robust watermarking are resistant to possible attacks such as image processing. Fragile watermarking can be easily destroyed or undetectable after modification is done on the image. But fragility is an advantage, where it can be used for authentication. The proposed scheme is done by embedding fragile watermark into the result of robust watermarking. The former is executed in the spatial domain and the latter is executed in the DWT. In order to prevent interference with the medical image, watermark is embedded by avoiding ROI. The proposed scheme can provide high robustness against median filter attack compared to other attacks. Research in [4] had implemented a reversible RONI for brain MRI scans. ROI is defined by using a rectangle that contains the whole head shape and is inserted in the RONI. In addition to other research, the embedding process in the RONI is adaptable. If RONI has enough space, the ROI is compressed in a lossless way and if not it is compressedin the best possible way before embedding occur. Watermarking is also used for other purposes other than to ensure authenticity and integrity. Medical image functionality is enhanced by using watermarking as proposed by [5]. Knowledge digest that gives a synthetic medical description of the medical image content is used for retrieving similar images with either same findings or different diagnoses. The knowledge digest is embedded as a reversible watermarking. Table 1 shows the PSNR and the type of domain used by the schemes reviewed in this section.

| Scheme | Domain | PSNR (DB) | Pros | Cons |
|---|---|---|---|---|
| 3 | DWT, Spatial | 19-51 | Robust against median filter attack | Time consuming |
| 4 | Spatial | 36-37 | Adaptive compression | Less robust |
| 5 | Spatial DCT | 37-42 | Knowledge digest | Higher digest |

**Table 1. Summary of PSNR and type of domain**

**Tamper detection and recovery**

The ability of to detect tampering of a watermarked image is crucial for authentication. Once tampering had been detected, the recovery of the tampered section can be done. We will review and compare watermarking two schemes that can perform the functions mentioned above in this section. Research by [6] has proposed that medical image is divided into blocks and each block is embedded with the authentication message and the recovery information of other blocks. The tamper detection is based on the robust watermarking combined with modulo addition. Example from the research uses a 1024 x 1024 pixels image and divides it into 16 blocks with the size of 256x256 pixels. Hash value is calculated for each block and JPEG bits from another block is retrieve before being embedded as watermark into another block. The detection of the tampering is done by comparing the hash value embedded together with the watermark and the hash value extracted from the image. If tampering is detected, recovery information is extracted from the corresponding block. The schemes can recover the whole image or only the ROI.Earlier research by [7] had also produced tamper detection and recovery watermarking. It also uses block based method with multiple hierarchies where each blocks consists of 8 x 8 pixels. Each block will then be divided into sub-blocks of 4X4 pixels. A 3-tuple watermark embedded consists of 2 bits authentication watermark and 7 bits recovery watermark for other sub-block. Average intensity of a corresponding block and its sub-blocks is calculated to generate authentication watermark. Average intensity of a sub-block will be embedded as the 7 bits recovery watermark in another block which was predetermined in a mapping sequence. A parity bit is generated based on the 7 bits recovery watermark. Detection of a tampered block is done by comparing the average intensity and parity bit. The detection of tampering is done in 3 levels from 4x4 pixel sub-blocks to 8x8 pixels blocks. Blocks that were mark invalid will be recovered. Table 2 shows the summary of the comparison between scheme proposed by [6] and [7].



| Scheme A[6] | Scheme B[7] |
|---|---|
| 1. Spatial and DCT<br>2. Less localization and image is divided into size of 256X256 pixels.<br>3. Low PSNR of 49 dB<br>4. Compare hash value<br>5. Uses of ROI<br>6. Single level detection | 1. Spatial<br>2. Better localization as image is divided into size of 8X8 and 4X4 pixels<br>3. Higher PSNR Of 55 dB<br>4. Compare average intensity.<br>5. No uses of ROI<br>6. Multilevel detection. |

**Table 2. Comparison summary between scheme A and scheme B**

## DISCUSSION

In this particular section, quality issues to be considered before a watermark scheme is chosen will be discussed.Watermarking schemes that were developed had been tested in the laboratories. In order to implement watermarking into existing medical information systems, it is crucial to choose suitable and reliable scheme. The performance of all watermarking schemes reviewed above had been measured only in terms of perceptibility. The higher is the PSNR value, the better it is. PSNR is one of the most widely used objective image quality/distortion metrics, but they are not correlating well with perceived quality measurement [8]. Therefore, additional evaluation such as clinical evaluation is needed to ensure the quality of the watermarked images. Clinical evaluation of watermarked medical images had been done by [9]. RONI were embedded with 256 bits hash value of the original image. Another method being evaluated is to embed watermark in both ROI and RONI with a total of 480K bits. Images from both methods were then accessed by consultant radiologists. It was concluded that watermarks used did not alter clinical diagnoses.It is also important to choose robust watermarking scheme to protect medical images from various attacks. Watermarking that uses spatial domain had been known to be less robust as compared to transform domain. But if we were to choose between two schemes for example between scheme proposed by [4] and [7] that uses spatial domain technique which is simpler and straight forward, we need to measure which scheme is more robust. BER (Bit error rate) between embedded message and extracted message can be used to evaluate the robustness of a watermarking [8]. The time requirement for the whole process of watermarking from encoding to decoding depends on the size of the image, algorithms used and the efficiency of the software programming [10]. As a comparison in terms of algorithm, scheme proposed by [6] that uses the combination of spatial and DCT domain is more complex than the scheme proposed by [7] that only uses spatial domain. It is important to choose a watermark scheme that fulfills the security needs of the medical images and at the same time does not affect the operation of the health institution in terms of time and computer resources.

## CONCLUSION

Watermarking in medical images provides promising alternative to current security tool used to protect the integrity of medical images. There are various types of watermarking scheme that uses different types of domains to ensure protection of medical images and perform recovery of a tampered image. Quality issues such as perceptibility of a watermarked image, robustness of the watermarking against attacks and time requirement needs to be considered before the implementation of a watermarking scheme into the medical information system. It is recommended that further work is needed before watermarking in medical images could be implemented. Watermarking needs to be tested in terms of image quality in a fully operational PACS(Picture Archiving and Communications Systems) where the medical images are stored and retrieved. Factor such as computer infrastructure that provides processing needs and transmissionswithin a network still can affect the performance of the watermarking process regardless of which watermarking scheme chosen.

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